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BOSTON SOCIETY OF CIVIL ENGINEERS
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PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, FEBRUARY 17, 1915,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. William S. Johnson will present a paper entitled, "Ground Water Supplies." The paper will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary*.

PAPERS IN THIS NUMBER.

"The Economic Depth of Trickling Filters," Harrison P. Eddy.

(Presented December 9, 1914.)

"The Depth of Filtering Material and Trickling Filter Efficiency," H. W. Clark.

(Presented December 9, 1914.)

Discussion of "Economic Depth of Trickling Filters."

"Toilet Regulations for Industrial Establishments." Report of Committee.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
" Commission-Manager Form of Government.	H. M. Waite.	Jan.	March 15.

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ANNUAL MEETING OF THE SOCIETY.

The annual meeting of the Society will be held on Wednesday, March 17, 1915, at the Boston City Club, Ashburton Place, Boston, where the accommodations will be even more satisfactory than those secured in former years at the old clubhouse.

The annual meeting for the transaction of business and the announcement of the result of the letter-ballot for officers will be held at 12 o'clock noon. A short address will be made by the retiring president.

The annual dinner will be served at two o'clock, in the banquet hall of the club.

In the evening a smoker will be held in the banquet hall, at which light refreshments, music and other entertaining features may be expected.

Further details will be furnished in a special circular to be sent out early next month and in the March JOURNAL.

ANNUAL MEETING OF THE SANITARY SECTION.

THE annual meeting of the Sanitary Section will be held Wednesday evening, March 3, 1915, at the Boston City Club.

Dinner will be served at 6.00 o'clock in one of the special dining rooms. It is expected that the new building will be available for this meeting.

The business meeting will begin at 7.30 o'clock. The business includes the following: Minutes of previous meetings,

reports of committees and election of officers for the ensuing year.

The speaker of the evening will be Mr. David A. Hartwell, Chief Engineer of the Sewage Disposal Commission, Fitchburg, Mass., who will present a paper on "The Fitchburg Sewage Disposal Works." The paper will be illustrated by lantern slides.

Make it a point to attend the annual meeting and enjoy a social evening.

FRANK A. MARSTON, *Clerk*.

MINUTES OF MEETINGS.

BOSTON, January 13, 1915. — A special meeting of the Boston Society of Civil Engineers was held this evening in the Society Rooms, at 8 o'clock, Vice-President Richard A. Hale in the chair. There were 36 members and visitors present.

Mr. Sanford E. Thompson read in part a paper prepared by him and Mr. William O. Lichtner, on "Construction Management." This paper was read at a meeting of the Western Society of Engineers held in Chicago on December 21, 1914, and by permission of that Society it is presented at this meeting for discussion.

The following, among others, took part in the discussion: Sanford E. Thompson, William O. Lichtner, J. Arthur Garrod and Leslie H. Allen. These discussions will be printed with the original paper in the *Journal of the Western Society of Engineers*.

Adjourned.

S. E. TINKHAM, *Secretary*.

BOSTON, January 27, 1915. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order at 8 o'clock by the senior Vice-President, Charles R. Gow. There were present 90 members and visitors.

By vote, the reading of the record of the last meeting was

dispensed with and it was approved as printed in the January JOURNAL.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members: Frederick Thornton Alden, Lloyd Elliot Baker, Roderick Stuart Barnes, Arthur Eliot Blackmer, Walter Keith Brownell, Byron Chapman Bussey, Joseph Lewis Carr, Martin Charles Cherry, Charles Francis Dingman, Henry Francis Dolliver, John Henry Duffy, Clyde M. Durgin, Charles Leavitt Edgar, Robert Benneson Farwell, Louis Ernst Flett, Philip Ely Fuller, John Patrick Gallagher, John M. Goodell, Thomas F. Gray, John Henry Griffin, Jesse Franklin Hakes, James Hayes, Jr., Charles Irwin Hosmer, Howard Chapin Ives, Charles D. Kirkpatrick, Arthur J. Knight, Harry Eleazer Lake, Alfred Rainford Mellor, Charles Augustus Miller, James Andrew O'Brien, Eugene Stewart Patton, Lew Knowlton Perley, Chauncey Rusch Perry, Frank Linwood Preble, Fred W. Proctor, John W. Raymond, Jr., Fred Burgess Skillin, George Carter Stone, Joseph Andrew Tosi, Winthrop Lodge Wales and Robert J. H. Worcester.

Associates: Walter T. Hoover and George Edwin Stuart.

Juniors: William Augustine Brown, William J. Cochran, Marshall Bertrand Dalton, Harold F. Davis, Robert Elwyn De Meritt, Walter C. Eberhard, Harrison Prescott Eddy, Jr., Victor Joseph Gallene, Raymond Daniel Gladding, John Baxter Hanna, Arthur William Knowlton, Millard Bartlett Pinkham, George Washington Simons, Jr., Stanley Armstrong Smith, Howard Cushing Thomas and Christian Frederick Wolfe.

On motion of Mr. George A. Carpenter, it was voted that the Chair be requested to appoint a committee of three to suggest to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The Chair appointed, as that committee, Messrs. George A. Carpenter, William S. Johnson and Ralph E. Curtis. Later in the meeting the committee reported the following names as members of the nominating committee, and by vote they were elected: Messrs. Arthur T. Safford, Frederic I. Winslow, Irving E. Moulthrop, Arthur L. Plimpton and Bertram Brewer.

The Secretary presented memoirs of deceased members prepared by committees of the Society as follows:

Memoir of Past President George B. Francis; committee, John W. Ellis and Edwin J. Beugler; Memoir of Lucian A. Taylor; committee, William E. McClintock and Frank E. Hall; and Memoir of Albert H. Howland; committee, Frederick Brooks and Frank L. Fuller. By vote, the Memoirs were accepted and ordered to be printed in the JOURNAL.

The chairman then introduced Mr. Nathan H. Daniels, a member of the American Institute of Electrical Engineers, who read a paper entitled, "Insurance as an Aid to Engineers." The paper was illustrated by lantern slides. A discussion followed the reading of the paper, in which Prof. Frank B. Sanborn, Mr. Daniels and others took part.

After passing a vote of thanks to Mr. Daniels for his interesting and valuable paper, the meeting adjourned.

S. E. TINKHAM, *Secretary*.

APPLICATIONS FOR MEMBERSHIP.

[February 6, 1915.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

M McNULTY, RICHARD JAMES, Boston, Mass. (Age 45, b. Dorchester, Mass.) Educated in Boston public schools. From 1888 to 1892, draftsman with Edward A. Buss, mill engineer, on mechanical and mill design; from 1892 to 1894, draftsman with the Boston Board of Survey and mill architect and engineer for several companies; from 1894 to 1896, with Percy N. Kenway and Prof. S. Homer Woodbridge, on heating and ventilating work; from 1896 to 1904, with the Metropolitan Sewerage Commission on general work including pumping station and machinery design; from 1904 to date, with the Boston Sewer Division on architectural, mechanical and sewer work. Refers to E. A. Buss, C. H. Dodd, E. S. Dorr and W. T. Wiley.

SMULSKI, EDWARD, Brookline, Mass. (Age 31, b. Pacykow, Austrian Poland.) Graduate of Imperial and Royal Polytechnic Inst., Lemberg, Austrian Poland, 1907. During year 1903-4 (fifteen months) draftsman and estimator with Bureau of Highways and River Improvements, Austrian Government; worked during vacations with M. of W. Dept., Austrian Government Railroads; from Nov., 1907, to April, 1910, with Sanford E. Thompson, cons. engr., as assistant engr.; from April to Aug., 1910, designer with Corrugated Bar Co., St. Louis; from Aug., 1910, to March, 1911, with Ralph Modjeski, civil engineer, Chicago, Ill., chiefly on bridge design; from April, 1911, to Sept., 1912, assistant bridge engineer, Louisville & Nashville R. R.; from Sept., 1912, to date, designing engineer with S. E. Thompson. Refers to R. D. Bradbury, B. S. Brown, S. E. Thompson and J. R. Worcester.

LIST OF MEMBERS.

ADDITIONS.

ATWATER, RALPH W.	I Avon St., Somerville, Mass.
BALSOR, FREDERICK N.	1176 Cambridge St., Cambridge, Mass.
BARNES, RODERICK S.	18 Federal Bldg., Albany, N. Y.
BLACKMER, ARTHUR E.	Town Engineer, Plymouth, Mass.
BUSSEY, BYRON C.	11 Star St., Pawtucket, R. I.
CURTIS, ALLEN	132 Centennial Ave., Gloucester, Mass.
GALLAGHER, JOHN P.	3 Green St., Watertown, Mass.
GOODELL, JOHN M.	34 May St., Worcester, Mass.
KIMBALL, HERBERT S.	111 Devonshire St., Boston, Mass.
HOSMER, CHARLES I.	54 High St., Turners Falls, Mass.
LAKE, HARRY E.	1307 Commonwealth Ave., Allston, Mass.
MELLOR, ALFRED R.,	
care Mass. Harbor & Land Comm., State House, Boston, Mass.	
RAND, ROBERT	220 Devonshire St., Boston, Mass.
SEARS, WALTON H.	60 Federal St., Boston, Mass.
SIMONS, GEORGE W., Jr.	63 Astor St., Boston, Mass.
STARR, JOHN A.	148 Irving St., Watertown, Mass.

PROCEEDINGS.

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STEARNS, RALPH H.....	1 Ashburton Place, Boston, Mass.
STONE, GEORGE C.....	60 Federal St., Boston, Mass.
WOLFE, CHRISTIAN F.....	214 West Canton St., Boston, Mass.
WOOD, CARL W.....	39 Greenleaf St., Malden, Mass.

CHANGES IN ADDRESS.

ACKERMAN, A. S.....	11 Francis St., Newport, R. I.
BARNES, ROWLAND H.....	93 Federal St., Boston, Mass.
CARPENTER, GEORGE A.....	55 High St., Pawtucket, R. I.
DURHAM, H. W.....	34 Gramercy Park, New York
FIELDING, WILLIAM J.....	225 Ashmont St., Dorchester, Mass.
MURPHY, EDWARD T.....	7 Hancock St., Boston, Mass.
NORWOOD, LEON O.....	Resident Engineer, Union, Me.
PETERS, ANTHONY W.....	53 Lincoln St., Boston, Mass.
RICH, MALCOLM.....	440 South Station, Boston, Mass.
SHAILER, ROBERT A.....	41st St. and Park Ave., New York
SHEDD, GEORGE G.....	290 Lexington St., Waltham, Mass.
THORPE, GEORGE H., Jr.....	Columbia Ave., Millville, N. J.
WALDSTEIN, JULIUS.....	21 Temple St., Boston, Mass.

EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society room two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

284. Age 23. Graduate of Mechanic Arts High School, 1908; student in civil engineering course, International Correspondence School. Has had six years' experience with Aspinwall & Lincoln, Boston, as rodman, transitman and, for about two years past, as surveyor; has thorough knowledge of calculation. Desires position as transitman or surveyer. Salary desired, \$15 per week.

285. Age 32. Graduate of Univ. of Maine, 1904. Has had over ten years' experience, mostly on construction work, including three years as resident engineer on hydro-electric construction, two years as resident

engineer on irrigation work and three years on municipal work. Desires position along any of these lines. Salary desired, \$125 per month.

286. Age 27. Graduate of Sheffield Scientific School, Yale Univ., electrical engineering course. Has had three months' experience in repairing shop of electrical department of Conn. Co., working mostly on motors, controllers, wiring of cars, lights, etc.; with General Electric Co., West Lynn, for short time in engineering course. Will accept any kind of electrical work in power station. Salary desired, \$15 per week.

287. Age 38. Graduate of Mass. Inst. of Technology, 1899. Experience includes about one year as rodman and instrumentman with Brookline Engineering Dept.; about ten years as draftsman, office assistant and assistant engineer with Metropolitan Sewerage Works; three years as assistant engineer in charge of business office and drafting-room at main office of Boston Elevated Ry. Co.; one year of private practice, surveying, plotting and drafting; one year inspecting construction of sewers, drains and streets for Brookline Engineering Dept. Desires position in office or on drafting room work, especially one affording experience in reinforced concrete design with engineer or contractor in or near Boston. Salary desired depends upon nature of work.

288. Age 30. Graduate of Toronto Univ. in mechanical and electrical engineering. Has had four years' experience with B. & A. R. R., on drafting and outside construction of track layout and docks; three years with Stone & Webster Engrg. Corp'n, on drafting and designing. Desires work in mechanical, electrical or general drafting and design. Salary desired, \$25 per week.

289. Age 29. Received degree of A.B. from Middlebury College, Vt., in 1908. Has had five years' experience as land surveyor and has done some drafting; also worked short time as rodman, chainman and transitman with civil engineer in Clinton, Mass. Desires position as transitman, rodman, draftsman or as general helper in an engineering office. Salary desired, from \$12 to \$18 per week.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Analyses of Mine and Car Samples of Coal Collected in Fiscal Years 1911 to 1913. Arno C. Fieldner and others.

Annual Report of Director of Bureau of Mines for 1913-14.

Geology and Oil Prospects in Waltham, Priest, Bitterwater and Peachtree Valleys, California. Robert W. Pack and Walter A. English.

Gold and Silver in 1913. H. D. McCaskey.

Gold, Silver, Copper, Lead and Zinc in Idaho and Washington in 1913. C. N. Gerry.

Gold, Silver, Copper, Lead and Zinc in Nevada in 1913. V. C. Heikes.

Some Deposits of Mica in United States. Douglas B. Sterrett.

Mineral Products of United States in 1912 and 1913. Edward W. Parker.

Production of Natural Gas in 1913. B. Hill.

Production of Petroleum in 1913. David T. Day.

Sampling and Analysis of Coal. Arno C. Fieldner.

Source, Manufacture and Use of Lime. Ernest F. Buchard and Warren E. Emley.

Results of Spirit Leveling in Virginia, 1900 to 1913, inclusive. R. B. Marshall.

Stone Industry in United States in 1913. Ernest F. Burchard.

Water-Supply Papers 326, 329, 345-G, 347, 366.

State Reports.

Maine. Report of State Board of Health for 1912 and 1913.

Massachusetts. Acts and Resolves of Legislature, Session of 1914.

Municipal Reports.

Baltimore, Md. Annual Report of Water Board for 1913.

Chicago, Ill. Report on Industrial Wastes from Stock Yards and Packingtown, 1914.

Providence, R. I. Annual Report of Public Works Department for 1914.

Miscellaneous.

American Sewerage Practice, Vol. II. Leonard Metcalf and Harrison P. Eddy. Gift of the authors.

American Society for Testing Materials. Proceedings for 1914, Part II. Gift of L. C. Wason.

Architekten-Fund Ingenieur-Verein zu Hamburg: Hamburg und seine Bauten, 2 vols. Gift of Desmond FitzGerald.

Boston Water Works: Clippings, 1885-1893. Gift of Desmond FitzGerald.

Capital. George L. Walker.

(The) General Education Board: Account of Its Activities, 1902-1914.

Notes on Catenary Construction of New York, Westchester and Boston Railway. Sidney Withington.

Universal Safety Standards. Carl M. Hansen.

LIBRARY COMMITTEE.

BOOK REVIEWS.

AMERICAN SEWERAGE PRACTICE, VOLUME I, DESIGN OF SEWERS, by Leonard Metcalf and Harrison P. Eddy; published by McGraw-Hill Book Co., Inc., New York, 1914. Cloth, 6 in. by 9 in., 747 pages, 328 illustrations, 172 tables. \$5.00.

Reviewed by Frederic P. Stearns.

The volume on the "Design of Sewers" is the first of three volumes intended to cover the whole field of American sewerage practice, and, as would be expected from the high standing and large experience of the authors in connection with sewerage work of all kinds, is a thoroughly practical book for the use of engineers engaged upon such work.

Too often books for engineers are written by those who have not had sufficient practical experience to enable them either to supply much original information or to use good judgment in compiling the results of the experience of others. This book, by contrast, shows throughout that the authors thoroughly understand their subject, that they are able as the result of their extended practice to furnish much original material, and that they have used good judgment in selecting from the practice

and experiments of others an immense amount of valuable material which has heretofore been scattered through engineering journals, reports and society publications.

One cannot fail to be impressed with the great amount of work involved in the preparation of the book, and readily accepts the statement in the preface that "the preparation of this book has demanded an amount of time and effort far in excess of that anticipated when the work was undertaken."

It is impracticable in a brief review to mention even the subjects of the many chapters, and if this were done they would not by themselves give an adequate idea of the breadth of treatment. All incidental questions which are likely to arise in designing sewers are discussed, and in addition many features are introduced to make it easier for the engineer in charge of a sewerage system to obtain records which will assist the sewer designers of the future.

For instance, in the chapter headed "Precipitation," all kinds of automatic rain gages are discussed and illustrated, and samples of the automatic records made by the gages are given. There is a short discussion of clock movements and of the setting and exposure of gages; then many diagrams are presented showing the intensity of precipitation during heavy rains of varying lengths in all parts of the United States, and in conclusion the subject of the frequency of heavy storms is discussed.

The hydraulics of sewers are very fully treated in all branches, including many allied features such as minimum grades and the transporting power of water. Many diagrams are provided to facilitate computations.

The chapters relating to the design of sewers and their many appurtenances have especial value, as the authors, by their researches and through the coöperation of other engineers, have obtained and illustrated a great number of examples of modern practice. This gives the engineer quick access to the designs of sewers and appurtenances which he could otherwise obtain only through a long search of reports and other engineering literature, and to many others which have never been published.

It is of interest to note that the authors in their preface acknowledge the cordial assistance of many other engineers and authors, and later state that "the book is at least a monument to coöperative effort and good-will among civil engineers." In the introductory chapter they refer to the wonderfully rapid progress in sewerage and sewage disposal in recent years, and state that the reason for this "will be found in that admirable spirit of good-will and coöperation existing among American engineers."

The book is a generous contribution by the authors to the progress of sewerage engineering, as its general purchase by those interested in sewerage engineering obviously cannot compensate in a monetary way for the immense amount of labor and expense involved in its preparation.

UNIVERSAL SAFETY STANDARDS, by Carl M. Hansen, M.E.
"A Reference Book of Rules, Drawings, Tables, Formulæ, Data and Suggestions for the Use of Architects, Engineers, Superintendents, Foremen, Inspectors, Mechanics and Students."
Compiled under the direction of and approved by the Workmen's Service Bureau, New York.

Reviewed by Edward F. Miller.

The author has divided the subject into four general groupings: I. General Safety Standards. II. The Machine Shop. III. The Foundry. IV. Rules for Practice.

Under General Safety Standards, such items as fire protection, design of stairs, safeguarding elevator openings and hatchways, safety devices for locking elevators, means for preventing overspeeding of engines, guards for power generating and power transmitting apparatus, boiler and main stop valves, care of dangerous gases, vapors, etc., have been treated.

Part II takes up in detail the methods of protecting the operation of machine tools and of the allied equipment in general use in large machine shops.

Part III treats with the same detail the protection of men working in a foundry.

Part IV in concise, clear wording gives in seven pages

"Rulès" for use of an operative in safeguarding himself from accident.

Parts I, II, III contain 206 pages of cuts illustrating the various devices which may be used in protecting the operatives.

This book through its illustrations will be found helpful to the owner of a shop or factory where there is machinery to be safeguarded, as well as to the engineers who may be installing machinery.

After looking at the elaborate systems of guarding to be seen on some of the cuts of machine tools one wonders why the makers of these tools have not before this considered the protection of the operative.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

United States Government. — NAVY DEPARTMENT. — *Navy Yard, Boston.* — A slip for ship construction is being built.

Commonwealth of Massachusetts. — METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — The tunnel and pipe line under Chelsea Creek, about 800 ft. above Meridian St. bridge, has been completed and is now in service. Work is in progress on the removal of the two 24-in. submerged pipe lines formerly used.

Sewerage Works. — The new screen house at the East Boston Pumping Station is the only work now under construction.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Charles River Reservation. — Plans are being prepared for construction of reinforced concrete and stone masonry arch bridge over the Charles River at North Beacon St., Boston and Watertown.

Middlesex Fells Parkway. — Reconstruction of burned portion of Wellington Bridge.

Winthrop Shore Reservation. — Constructing sea wall at northerly end of reservation.

Boston Transit Commission. — *Dorchester Tunnel.* — The Dorchester Tunnel is substantially completed from Tremont St. to the westerly side of Dewey Square, with the exception of the interior finish in the Washington station, which extends from Washington to Chauncy St. The work of finishing the station is nearing completion.

Section D includes a station under Dewey Square and about 450 ft. of tunnel under Summer St. east of the station. Work is now in progress on both station and tunnel. The Hugh Nawn Contracting Co. is the contractor.

Section E includes two single-track circular tunnels which will extend from near the junction of Summer St. and Dorchester Ave. under Fort Point Channel and private property to a point near Dorchester Ave. between West First and West Second Sts., South Boston. These tunnels will be driven by means of shields and with compressed air. Work has begun on the main shaft in West First St. P. McGovern & Co. are the contractors.

Enlargement of Park Street Station. — A brief description of the work for the enlargement of Park St. Station was given in the December issue of this Journal. The work is now nearly completed. There yet remains to be done the work of lowering parts of the platforms of the old station, the completion of the interior finish on the walls and ceiling of the enlargement, and a few minor details. Coleman Bros. are the contractors for building the enlargement.

East Boston Tunnel Extension. — Northwesternly of Cornhill, extending to North Russell St., the tunnel has been completed with the exception of the station finish, stairways, entrances and exits. In Court St., between Franklin Ave. and Cornhill, the sidewalls of the tunnel have mostly been built. The invert of the East Boston Tunnel is being removed and the earth underneath excavated to the new grade. The steel

columns and beams are being set to support the old roof which is to remain in place.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Spring Street, between Gardner and Webster streets, excavating and grading.

Temple Street, between Spring to Ivory streets, excavating and grading.

Deering Road, between Blue Hill Avenue to Harvard Street, excavating and grading.

Seaver Street, between Walnut and Humboldt avenues, excavating and grading.

East First Street, sea wall.

PUBLIC WORKS DEPARTMENT, SEWER AND WATER DIVISION, SEWER SERVICE. — The following work is in progress:

Union Park Street Pumping Station, South End. — Installing suction and discharge pipes.

Beach Street at Lincoln Street, City Proper. — Reinforced concrete sewer replacing old wooden sewer.

Milton Street, Hyde Park. — Ejector station, ready to be tested January 27.

Davenport Brook Conduit. — Dorchester; in progress.

DIRECTORS OF THE PORT OF BOSTON. — *Bulkheads.* — Work is in progress under this contract and the work is now about 95 per cent. completed.

Dredging. — The dredging of the Reserved Channel in South Boston easterly from the L Street bridge is in progress under two contracts, making a channel with 30 ft. of water at mean low water and a width of 300 ft. The suction dredge *Tampa* is discharging filling into the bulkhead on the south side of the dry dock site.

Designing. — Studies are being made for the comprehensive development of the port.

New York, New Haven & Hartford Railroad. — CLINTON, MASS. — *Elimination of Grade Crossings.* — New passenger station has been put into service, practically completing the elimination of grade crossings.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

U. S. Battleship *Nevada*.

Eight U. S. submarine boats.

U. S. Torpedo Boat Destroyers *Cushing*, *Tucker* and Nos. 63 and 64.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

THE ECONOMIC DEPTH OF TRICKLING FILTERS.

BY HARRISON P. EDDY, PRESIDENT, BOSTON SOCIETY OF CIVIL
ENGINEERS.

(Presented before the Sanitary Section, December 9, 1914.)

IN a paper entitled "Economics of Sewage Filters," presented to the recent convention of the American Society of Municipal Improvements by George W. Fuller, M.Am.Soc.C.E., the author presents certain theories and computations relating to the economic depth of trickling filters. He concludes with the following statement: "Taking everything into account, the writer believes that a sprinkling filter bed of not less than 6 ft. and not more than 7 ft. will, in a great number of cases, prove the most economical to use."

Mr. Fuller's paper is interesting as it touches upon one of the problems which has caused much perplexity in the minds of engineers designing sewage treatment plants. In connection with the design of the trickling filters for the city of Fitchburg, Mass., the writer made a study of the results obtained by the operation of various experimental and practical trickling filters. At the conclusion of this study, the evidence seemed to point more strongly toward the confirmation of the conclusions of the Royal Commission to the effect that the capacity of trickling

NOTE. A discussion of this paper is printed elsewhere in this number of the JOURNAL. Further discussion is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before April 15, 1915, for publication in a subsequent number.

filters is substantially proportional to their cubic contents, regardless of depth, rather than toward those of Mr. Fuller.

It is quite remarkable that, of all of the experimental filters which have been operated in this country, there seems to have been no group of filters of equal areas and different depths which have been operated by applying the greatest quantities of sewage which could be treated and produce effluents of practically uniform quality.

A majority have been operated to show the effect upon the degree of purification of the depth of stone with the same quantity of sewage per unit of surface area instead of per unit of volume of filtering medium. It is very hard to draw reliable conclusions as to the economic depth of filters from varying degrees of purification obtained by means of filters of various depths. On the other hand, the relative merits of the deep filter over those of the shallow filter could have been determined readily if the filters had been dosed with the quantities of sewage per cubic yard of filtering material which would have produced effluents of substantially equal quality.

However, it is possible to select certain of the trickling filters, the results of the operation of which can be compared with some accuracy, to throw light upon this question.

Under ordinary conditions the load upon the filter can perhaps be most readily determined if computed in terms of grams of nitrogen per cubic yard of filtering material. These figures can be converted into number of persons served per cubic yard of material by assuming a given quantity of nitrogen per person as 15 grams per capita of unoxidized nitrogen, including free ammonia and total organic nitrogen. Such a comparison of the operating results of a number of trickling filters can be made from data given in Table 1.

The Gloversville experiments given in this table indicate that the 10-ft. filter, although treating a greater quantity of nitrogen per cubic yard, produced nearly as good an effluent as the 7-ft. filter and a better effluent than the 5-ft. filter.

The Worcester experiments indicate a similar result, and at times the 10-ft. filter was producing a stable effluent at higher rates per cubic yard than the shallower filters.

ECONOMIC DEPTH OF TRICKLING FILTERS.

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TABLE I.
WORK ACCOMPLISHED BY TRICKLING FILTERS OF DIFFERENT DEPTHS.

Location.	Filter No.	Depth. Ft. In.	Size of Stone, Inches.	Nitrogen Ap- plied, Grams per Cu. Yd.	Cu. Yds. Filtering Material Required per Person.	Per Cent. of Samples Stable.	Period of Opera- tion.	Character of Sew- age Applied.
Gloversville, N. Y.	3	5-0	1 1/2	6.90	2.2	32.2	3 months	Septic
Gloversville, N. Y.	2	7-0	1 1/2	5.96	2.5	100	3 months	Septic
Gloversville, N. Y.	1	10-0	1 1/2	6.95	2.2	91.6	3 months	Septic
Worcester, Mass.	D	5-0	3 2 1/2	10.52	1.4	70	1 year	Settled
Worcester, Mass.	F	7-6	3 2 1/2	10.02	1.5	93	2 months	Settled
Worcester, Mass.	E	7-6	3 1 1/2	11.0	1.4	100	1 year	Settled
Worcester, Mass.	H	10-0	3 2 1/2	10.40	1.4	88.9	4 months	Imhoff tank
Worcester, Mass.	G	10-0	3 1 1/2	10.4	1.4	100	4 months	Imhoff tank
Lawrence, Mass.	247	5-0	1-1	25.7	0.6	40-78	3 years	Unsettled
Lawrence, Mass.	248	8-0	1-1	16.6	0.9	90-100	3 years	Unsettled
Lawrence, Mass.	248	8-0	1-1	25.4	0.6	90-100	4 years	Settled
Lawrence, Mass.	135	10-0	1-1	16.4	0.9	100	1 year	Unsettled
Lawrence, Mass.	136	10-0	1-1	28.2	0.5	100	2 years	Settled
Lawrence, Mass.	136	10-0	1-1	29.7	0.5	70	1 year	Settled
Lawrence, Mass.	136	10-0	1-1	22.6	0.7	100	3 years	Unsettled
Lawrence, Mass.	135	10-0	1-1	19.1	0.8	100	4 years	Settled
Lawrence, Mass.	135	10-0	1-1	17.0	0.9	100	1 year	Settled
Lawrence, Mass.	135	10-0	1-1	18.7	0.8	100	4 years	Settled

The experiments made at Lawrence, Mass., and given in Table 1, also indicate the same results, that up to a limit of depth of 10 ft. the capacity of a trickling filter is directly proportional to its depth.

There may be a greater tendency to pooling with the deep filter on account of the greater quantity of sewage applied per unit of superficial area and a slightly less circulation of air; but, on the other hand, the deep filter may have some advantage because of the lessened effect of low temperatures of winter in severe climates, and a smaller surface area from which odors are likely to be given off.

From the foregoing it seems that there is at least as good ground for assuming that a filter 10 ft. in depth will do as much work per cubic yard of stone as one 6 ft. in depth, as there is for Mr. Fuller's assumption that the unit capacity of a filter decreases with its depth in 6-, 8-, and 10-ft. beds. The importance of this difference in assumptions is very great, as will be shown by a comparison of the cost of filters of various depths.

In making such a comparison, it would seem to be more accurate to vary the cost of the walls according to their length and height, rather than in proportion to the cubic yards of stone contained in the filter, as was done by Mr. Fuller. The difference, however, is not great.

In computing the comparative costs of the distribution system, Mr. Fuller assumed that they vary only according to the quantity delivered and that they must be the same per cubic yard for all effective depths. It seems to the writer that this is a wrong assumption and that the distribution system is much more likely to vary in proportion to the area of the filter.

The comparative costs of filters from 6 to 10 ft. deep (the 10-ft. filter computed by the writer), based upon Mr. Fuller's assumptions and those of the writer, are given in Tables 2 and 3, the unit prices being those adopted by Mr. Fuller.

The unit prices assumed in the paper are extremely low, and it may be of interest to make similar computations based on the prices actually bid for the construction of the sewage treatment works at Fitchburg, Mass., which have just been completed. Such comparisons figured by the methods proposed by

TABLE 2.

RELATIVE COSTS OF TRICKLING FILTERS OF DIFFERENT DEPTHS. BY GEORGE W. FULLER.*

Depth of stone in feet.....	COST PER EFFECTIVE CU. YD.			
	6	7	8	10
Floor at \$0.40 per cu. yd. for 6-ft. bed...	\$0.40	\$0.35	\$0.32	\$0.29
Tile at 11c per sq. ft.....	.49	.44	.40	.36
Walls at cost \$0.17 per cu. yd. for 6-ft. depth.....	.17	.17	.18	.21
Galleries and collectors at \$0.25 per cu. yd. for 6-ft. depth.....	.25	.22	.20	.18
Distribution at \$0.50 per cu. yd., same for all effective depths per cu. yd....	.50	.50	.50	.50
Stone at \$1.50 per cu. yd.....	1.50	1.55	1.60	1.83
Total.....	\$3.31	\$3.23	\$3.20	\$3.37

NOTE: Fuller assumes relative value of stone per cubic yard to be as follows:

Depth of bed.....	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.	12 ft.
Value.....	1.0	0.97	0.94	0.92	0.82	0.63

In computing relative costs, the unit costs for 6-ft. filter are decreased where necessary, in proportion to the volume of the deeper filters, and divided by the above factors.

TABLE 3.

COST OF TRICKLING FILTERS OF VARIOUS DEPTHS PER EFFECTIVE CU. YD. BY EDDY'S METHOD, BASED ON FULLER'S PRICES.

Depth of stone in feet.....	6	7	8	10
Relative value of stone per cu. yd.....	1.0	1.0	1.0	1.0
Relative volumes of stone.....	1.0	1.0	1.0	1.0
Relative areas of filtering surface.....	1.0	0.857	0.75	0.60
Relative extent of walls (area).....	1.0	1.12	1.15	1.29
Floor at 40c per cu. yd. 6-ft. filter.....	\$0.40	\$0.34	\$0.30	\$0.24
Tile at 11c per sq. ft.....	.49	.44	.40	.36
Walls at 17c per cu. yd. 6-ft. filter....	.17	.19	.20	.22
Galleries and collectors at 25c per cu. yd. 6-ft. filter.....	.25	.21	.19	.15
Distribution at 50c per cu. yd. 6-ft. filter,	.50	.43	.38	.30
Stone at \$1.50 per cu. yd.....	1.50	1.50	1.50	1.50
Total.....	\$3.31	\$3.11	\$2.97	\$2.77

NOTE: In computing this table the unit costs of a 6-ft. filter are decreased where necessary, in proportion to the quantity, as of floor area per cubic yard of stone, and divided by Fuller's factors.

Mr. Fuller and the writer, respectively, are given in Tables 4 and 5. From these figures it will be seen that whereas on Mr.

* Computations relating to filter 10 ft. deep made by writer.

Fuller's assumption the price per effective cubic yard varies relatively little, from \$4.33 to \$4.56, when computed on the

TABLE 4.

COST OF TRICKLING FILTERS OF VARIOUS DEPTHS PER EFFECTIVE CU. YD.,
BY GEO. W. FULLER'S METHOD BUT BASED ON FITCHBURG PRICES.

Depth of stone in ft.	6	7	8	10
Relative value of stone per cu. yd.	1.0	0.97	0.94	0.82
Relative volumes of stone.	1.0	1.03	1.06	1.22
Relative areas of filtering surface.	1.0	0.88	0.80	0.73
Floor at \$1.30 per cu. yd. for 6-ft. filter varies as area.	\$1.30	\$1.14	\$1.04	\$0.95
Walls at 14½c per cu. yd. for 6-ft. filter (varies as volume of stone).	.15	.15	.15	.18
Underdrains and gallery at 34c per cu. yd. 6-ft. filter (varies as area).	.34	.30	.27	.25
Distribution at 80c per cu. yd. 6-ft. filter (constant).	.80	.80	.80	.80
Stone at \$1.95 per cu. yd.	1.95	2.01	2.07	2.38
Total.	\$4.54	\$4.40	\$4.33	\$4.56

TABLE 5.

COST OF TRICKLING FILTERS OF VARIOUS DEPTHS PER EFFECTIVE CU. YD.,
BY EDDY'S METHOD BASED ON FITCHBURG PRICES.

Depth of stone in feet.	6	7	8	10
Relative value of stone per cu. yd.	1.0	1.0	1.0	1.0
Relative volumes of stone.	1.0	1.0	1.0	1.0
Relative areas of filtering surface.	1.0	0.857	0.75	0.60
Relative extent of walls (area).	1.0	1.12	1.15	1.29
Floor at \$1.30 per cu. yd. 6-ft. filter (varies as area).	\$1.30	\$1.11	\$0.98	\$0.78
Walls at 14½c per cu. yd. 6-ft. filter (varies as walls).	.15	.17	.17	.19
Underdrains and gallery at 34c per cu. yd. 6-ft. filter (varies as area).	.34	.29	.26	.20
Distribution at 80c per cu. yd. 6-ft. filter (varies as area).	.80	.69	.60	.48
Stone at \$1.95 per cu. yd. (varies as volume of stone).	1.95	1.95	1.95	1.95
Total.	\$4.54	\$4.21	\$3.96	\$3.60

assumptions made by the writer the differences are substantial, the range in price being from \$3.60 for the 10-ft. filter to \$4.54 for the 6-ft. filter.

This may be presented in a somewhat more effective manner by applying the prices to filters of varying depths, capable of doing the same work as a filter one acre in area and 6 ft. deep. These computations are given in Table 6, from which it appears

TABLE 6.

COST OF TRICKLING FILTERS OF VARIOUS DEPTHS TO DO THE WORK
OF 1 ACRE, 6 FEET DEEP.

(Assume filters square in plan.)

Depth of stone in feet.....	6	7	8	10
Relative value of stone per cu. yd. (H.P.E.)	1.0	1.0	1.0	1.0
Relative volumes of stone.....	1.0	1.0	1.0	1.0
Relative areas of filtering surface.....	1.0	0.857	0.75	0.60
Relative extent of walls (areas).....	1.0	1.12	1.15	1.29
Floor system at \$2.60 per sq. yd.....	\$12 580	\$10 780	\$9 440	\$7 540
Walls at \$2.00 per sq. yd. (718 sq. yd. in 6-ft. filter).....	1 436	1 608	1 650	1 852
Underdrains and gallery at 68½¢ per sq. yd. (area).....	3 315	2 840	2 480	1 988
Distribution system at \$1.60 per sq. yd. (area).....	7 773	6 666	5 830	4 666
Stone at \$1.95 per cu. yd.....	18 880	18 880	18 880	18 880
Total, exclusive of engineering and excavation.....	\$43 984	\$40 774	\$38 280	\$34 926

that a filter 10 ft. deep need have an area but six tenths as great as that of a filter 6 ft. deep. It is, therefore, to be expected that the cost of floor system, underdrains, galleries and distribution system will be materially less in the case of the deeper filter, while the cost of the walls for the deeper filter will be increased. If the assumptions upon which these computations have been based are correct, the cost of a filter 10 ft. in depth, to do the work which could be accomplished by a filter one acre in area and 6 ft. deep, will be \$34 926, whereas the filter 6 ft. deep would cost \$43 984. The reduction in cost, therefore, amounts to slightly over 20 per cent. All of these computations are exclusive of excavation.

It is unfortunate that there are no better data upon which to predicate an assumption as to the relative capacities per cubic yard of filtering media in deep and shallow filters. There

can be no doubt that there is a practical limit to the economic depth of trickling filters. This limit will vary according to local conditions and must be computed for each case. There seems to the writer, however, much evidence that up to a certain limit, which in most cases where municipal sewage is to be treated will be as high as 8 or 10 ft., the capacities of the filters will be approximately uniform per cubic yard of filtering material.

This brief paper is presented with a view to pointing out the importance of the difference between the two theories described, with a hope that some one will have an opportunity to carry out for a considerable period of time a series of experiments to determine the point at issue. Conclusions as to the efficiency of filters — particularly deep ones — must not be based upon too short periods of operation, for it takes considerable time for a deep filter to become thoroughly seeded throughout its depth, and until it does it cannot do its normal amount of work.

Since preparing the foregoing paper the writer's attention has been directed to a reprint from the Forty-fifth Annual Report of the Massachusetts State Board of Health, recently issued for distribution. In this report, Messrs. H. W. Clark and Stephen DeM. Gage describe the beginning of an experiment to determine the "relative rates necessary to obtain effluents of equal quality from trickling filters of different depths." This experiment appears to be exactly in accord with that suggested in the foregoing discussion. These filters are 4, 6, 8 and 10 ft. in depth, respectively, and the results at the end of the period covered by the report — May 1, 1913, to December 1, 1913 — appeared to indicate that the deeper filters had a capacity per cubic yard at least equal to, if not greater than, the similar capacities of the shallower filters. The results of the past year (1914) will prove of great interest and, in the writer's opinion, of distinct value as furnishing reliable information upon this important subject.

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PAPERS AND DISCUSSIONS

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THE DEPTH OF FILTERING MATERIAL AND
TRICKLING FILTER EFFICIENCY.

BY H. W. CLARK, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented before the Sanitary Section, December 9, 1914.)

THE maximum results in efficiency of purification and volume of sewage purified in trickling filter sewage purification are obtained when the filter is of considerable depth and is constructed of comparatively fine material. There is undoubtedly a maximum depth beyond which the additional efficiency obtained is not commensurate with the additional cost of construction, and which interferes with filter aëration, and a minimum depth below which economical rates of filtration cannot be maintained. In cöordination with the depth, a filtering material should be selected that will have the greatest efficiency at that depth when the filter is operated at economical rates and yet be coarse enough to preclude clogging of the filter and, if possible, surface pooling.

During a period of sixteen years, broken stone trickling filters have been operated at Lawrence, constructed with depths of material varying from 4 to 10 ft. and with stone varying from 1 in. to 6 ins. in diameter. The rates of operation have varied

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by April 15, 1915, for publication in a subsequent number of the JOURNAL.

from 250 000 to 10 000 000 gals. per acre daily. Three of these filters, 5, 8 and 10 ft. in depth and operated for periods of five, eleven and fifteen years, respectively, gave average rates and results during these periods of operation shown in the following table.

TABLE I.

Filter No.	Depth. (Ft.)	Period of Operation. (Years.)	Average Rate. (Gallons per Acre Daily.)	Nitrates. (Parts per 100 000.)	Percentage of Stability.
247	5	5	1 465 000	0.97	44
248	8	11	1 630 000	1.00	90
135	10	15	2 000 000	2.10	99+

These three filters, used for various studies of trickling filter purification, received at different times sewage of varying strength, and hence the results in regard to purification and stability of effluents are not strictly comparable with their rates of operation. However, the table shows that with the sewage applied, the 5-ft. filter was operated at a rate altogether too high to obtain suitable stability of effluent, that the 8-ft. filter gave fairly satisfactory results even at the high average rate maintained and that the 10-ft. filter could have been operated at a much higher rate and still have produced a stable effluent.

On May 1, 1913, four new trickling filters were put into operation at the station to study this point; namely, to determine at what rates filters constructed of different depths and of the same material must be operated in order to obtain effluents of equal quality. Each of these filters is constructed of pieces of broken stone between $\frac{3}{4}$ in. and $1\frac{1}{2}$ in. in size. Filter No. 452 is 4 ft. in depth; Filter No. 453, 6 ft.; Filter No. 454, 8 ft.; and Filter No. 455, 10 ft. The sewage applied to each has been clarified by sedimentation. We have attempted to operate each filter at such a rate that the effluents will contain about 1.5 parts nitrates per 100 000, this being the amount of nitrification which previous experience at the station has shown to be necessary in order to insure stable effluents in trickling filter

purification. Each filter was operated at first at a rate of 1 000 000 gals. per acre daily. On August 15, 1913, the two deep filters — Nos. 454 and 455 — were producing well-nitrified effluents, and the rate of each was increased to 1 250 000 gals. per acre daily. As the two shallow filters had not up to this time given satisfactory results, the rate of No. 452, the 4-ft. filter, was reduced to 500 000 gals., and that of No. 453, the 6-ft. filter, to 800 000 gals. per acre daily, and later to 140 000 and 200 000 gals. per acre daily, respectively. Even at these low rates, however, the effluents from these two shallow filters did not average up to the required standard of stability and nitrification. Nitrification in the deep filters continued to increase, and during October and the early part of November the rate of the 8-ft. filter was gradually advanced to 2 000 000 gals., and that of the 10-ft. filter to 2 500 000 gals. per acre daily.

The average rates of operation and analyses of the effluents from these filters during this first year are given in the following table. In this table the percentage of stability given to the effluents of the shallow filters is due to the fact that during a considerable portion of this period they were being operated at rates much lower than the averages given in the table.

TABLE 2.
AVERAGE ANALYSES OF EFFLUENTS.
(Parts per 100 000.)

Filter No.	Depth, Ft.	Quantity Applied. Gallons per Acre Daily.	Ammonia, Albuminoid.			Chlorine.	Nitrates.	Oxygen Consumed.	Percentage of Stability.
			Free.	Total.	In Solution.				
452	4	637 100	1.4083	.2858	.1947	14.33	1.08	1.98	83
453	6	798 000	1.3442	.1958	.1467	14.23	1.04	1.37	90
454	8	1 231 300	0.9542	.2168	.1560	14.14	1.53	1.65	99+
455	10	1 355 300	0.9833	.2533	.1773	13.87	1.85	1.89	99+

Early in 1914 these filters reached a condition of equal biological activity and it was possible to so adjust their rates that practically equal effluents were obtained, and the results for this year are shown in Table 3.

TABLE 3.

AVERAGE CHEMICAL ANALYSES OF EFFLUENTS FROM DECEMBER, 1913, TO
SEPTEMBER, 1914, INCLUSIVE.

(Parts per 100 000.)

Filter No.	Quantity Applied. Gallons per Acre Daily.	Ammonia, Albuminoid.			Chlorine.	Nitrogen as		Oxygen Consumed.	Percentage of Stability.
		Free.	Total.	In Solution.		Nitrates.	Nitrites.		
452	332 700	1.8600	.3050	.2006	13.20	1.63	.0065	1.89	85
453	585 100	1.2900	.2950	.1796	13.30	1.81	.0128	1.79	91
454	1 801 000	1.3575	.3715	.2292	12.98	1.66	.0126	2.17	88
455	3 733 000	1.7275	.3900	.2616	13.48	1.76	.0081	2.38	85

Table 4 is of interest in showing the lower nitrification and stability of effluent of the two shallower filters when operated at rates considerably higher than the yearly average.

TABLE 4.

AVERAGE CHEMICAL ANALYSES OF EFFLUENTS FOR TWO MONTHS WITH
HIGHER RATES OF FILTRATION.

(Parts per 100 000.)

Filter No.	Quantity Applied. Gallons per Acre Daily.	Ammonia, Albuminoid.			Chlorine.	Nitrogen as		Oxygen Consumed.	Percentage of Stability.
		Free.	Total.	In Solution.		Nitrates.	Nitrites.		
452	524 000	2.6250	.3425	.2320	13.00	0.94	.0070	2.00	56
453	721 000	1.9500	.3300	.2200	12.70	1.21	.0070	1.88	67

CONCLUSIONS.

All of these filters are constructed of comparatively fine broken stone averaging about one inch in diameter, and they are, of course, operated under ideal conditions; that is, under such supervision and care as is almost impossible to actually duplicate in practice. This does not affect their comparative

results, however. Judging from these results, the deeper filters are much more economical than the shallower filters as they allow greater rates, foot for foot. The maximum average rate of filtration per foot of depth with filters of the depths studied, with equal nitrification and stability of effluent, during 1914, was as shown in the following table. In this table are also presented figures showing what probably will be the average rate of filtration per foot in depth with these filters after they have been in operation for a longer period. It is evident from these figures and those in Table 3 that the rates of filtration that can be maintained increase much faster than the depths.

TABLE 5.

GALLONS FILTERED PER ACRE DAILY PER FOOT OF FILTER DEPTH,
WITH EQUAL NITRIFICATION AND STABILITY RESULTS.

	According to 1914 Rates.	According to Prob- able Rates over a Considerable Period.
With a 4-ft. filter.....	85 000	100 000
With a 6-ft. filter.....	100 000	125 000
With an 8-ft. filter.....	225 000	200 000
With a 10-ft. filter.....	370 000	300 000

In Table 6, figures are given showing the actual increase in volume of sewage per acre that can be filtered daily for each foot in depth additional above six feet and above eight feet in depth; that is, judging from these 1914 results. Moreover, studying certain previous work with trickling filters at Lawrence, this remarkable increase of efficiency in rate purification of the deeper filters seems to hold true.

TABLE 6.

Gain in Actual Rates of Filtration per Acre for Each Foot.	Gallons per Acre Daily.
Above 6 ft. in depth.....	550 000
Above 8 ft. in depth.....	750 000

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PAPERS AND DISCUSSIONS

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DISCUSSION OF THE ECONOMIC DEPTH OF TRICKLING FILTERS.

MR. GEORGE W. FULLER (*by letter*). — The writer has read with keen interest the paper of Mr. Eddy upon the "Economic Depth of Sprinkling Filters" and has noted in particular the position taken that there is much evidence to show that up to a certain limit, in most cases as high as 8 or 10 ft., the capacities of filters of this type will be approximately uniform per cubic yard of filtering material. From this deduction it follows that economically it is preferable, where the head is available, to build sprinkling filters of greater depth than the 7-ft. limit suggested in an earlier paper by the writer on the "Economics of Sewage Filters," presented last October before the American Society of Municipal Improvements.

The writer agrees with the majority of the points set forth by Mr. Eddy. It goes without saying that the conclusions should and would be identical if the premises were the same. The writer based his views partly on general observation of European and American filters on a practical scale, but more particularly upon the data from experimental filters at Baltimore and the results obtained from the first large sprinkling filter on a working scale in this country at Reading, Pa. Mr. Eddy bases his views upon data from Gloversville, Worcester and Lawrence, but with a different yardstick for measuring relative efficiencies.

There is agreement on the proposition that this question.

is an important one and that the available data of a directly comparable nature are very meager and, in fact, almost lacking save for the interesting small-scale tests at Lawrence, conducted for a fairly short period, as outlined by Mr. Clark. The writer also agrees that this question is one for detailed study on each large project and that the conclusions deduced for one project are not necessarily correct for another problem under different local conditions.

Our comments after re-reading the original paper and Mr. Eddy's discussion thereof are as follows:

PREVAILING PRACTICE.

Within the range of the writer's observation the vast majority of sprinkling filters have a depth ranging from about 5 ft. to $8\frac{1}{2}$ ft. Exceptions to this range are to be found for deeper filters in the case of very coarse material called by the Germans "fist size"; or with very fine material, such as noted in the shallow beds of fine saggars at Hanley, England. Excepting Mr. Eddy's important project at Fitchburg, Mass., most of the recent sprinkling filters in this country have been based on a depth of $6\frac{1}{2}$ to 7 ft. There are a few with shallower depths, necessitated by local conditions as to available head, such as at Schenectady, N. Y. The $8\frac{1}{2}$ -ft. beds at Baltimore were occasioned largely by the desire to get a removal of bacteria somewhat greater than ordinarily had been the experience with shallower beds elsewhere.

The writer attaches much importance to the fact that the sprinkling filters at Reading, Pa., have required progressively the installation of additional units, due to the existing ones receiving as high a load as could be safely carried without unreasonable pooling and clogging at the surface. In other words, if the beds were materially deeper, it does not seem likely that any more sewage could have been rendered non-putrescible, although it is granted that a higher degree of nitrification would have been found in the effluent. It is realized, however, that this deduction is not necessarily decisive on broad lines, because with the elimination of some of the finer particles of the Reading

filtering material the clogging factor would have been somewhat reduced.

Speaking generally, the Fitchburg design and the teachings of the experiments as described in Mr. Eddy's discussion point to a departure from what might be called normal practice, and it is believed to be fair to point out that while the data are admittedly incomplete, the burden of proof rests with those making the departure from prevailing practice. Particularly is this so, as the data of Mr. Eddy are at variance with those from Baltimore, as given by the writer, and those from Hanley and Leeds, England, as summarized by Kinnicutt, Winslow and Pratt.*

DURATION OF TESTS.

Mr. Eddy is correct in pointing out that this is an item of much significance. Nitrification in the lower portions of deep beds is probably not established until some time after the filter is put in service. On the other hand, surface clogging does not develop until the plant has been in service for some time.

Uniformity of distribution of sewage is another item of importance. It is influenced by surface clogging to some extent, but it is true that deeper beds have a steadying influence on distribution which is more marked than in the case of shallow beds, other things being equal.

These comments are made in particular to point out that too much weight should not be given to the results obtained from small-scale tests of relatively short duration.

COMPARISON OF EFFICIENCY.

The inadequacy of the yardstick for measuring the relative efficiency of sprinkling filters of different depths is one of the chief factors in causing discordant data and varying conclusions to be drawn therefrom. It is one of the differences between the writer's comments on the Baltimore data and the statements of Mr. Eddy concerning the Gloversville, Worcester and Lawrence data. The writer has dealt with relative

*"Sewage Disposal," page 332.

stability and oxygen-consumed results, whereas Mr. Eddy has measured the work accomplished by the percentage of samples showing the effluent to have been stable. The strength of the sewage he has measured in terms of unoxidized nitrogen, including free ammonia and organic nitrogen.

The uncertainties attending this method of rating the work accomplished may readily disguise the well-known fact that the upper portions of the filters generally do more work than the lower portions. This latter statement is based partly upon the results of inspection showing a greater detention of organic matter and zooglœa which, so long as aëration is ample, we have been taught to believe promotes biochemical activities accomplishing purification to a greater extent than is effected by passing over the cleaner stone in the lower portion of the filter. This may not be true as regards complete nitrification, but it is believed to be so so far as freeing the sewage of putrescible organic matter is concerned. It is generally supported by the Hanley and Leeds data, cited above.

SIGNIFICANCE OF NITRIFICATION.

The Massachusetts data, especially those at Lawrence, seem to be interpreted as regards efficiency of coarse-grained filters, with a higher regard for nitrification than is true at many places elsewhere. Thus it is stated that the Lawrence filters were subjected to an operating schedule such as to cause the effluents to contain about 1.5 parts per hundred thousand of nitrogen as nitrates. This is quite a different policy from that adopted by the writer. At Reading, Pa., for instance, as described in the writer's book on "Sewage Disposal," page 695, the sprinkling filter effluents were uniformly stable and did not on an average contain half as much nitrates as above-mentioned. Quoting again from the same book, it is noted on page 674 that the Plainfield filters contain only about one quarter as much nitrates as mentioned in the Lawrence procedure, although the effluents as a rule were non-putrescible. During the summer months the final effluent, undiluted, was occasionally putrescible, but this was rarely if ever the case during the eight colder months of the year.

Attention here is directed to the fact that low nitrification in the sand filters at Lawrence during the winter of 1901-02 accompanied non-putrescible effluents, as stated in the 1901 Report of the Massachusetts State Board of Health, page 308, and in the 1902 Report, page 214.

Nitrates unquestionably promote the stability of the effluents of coarse-grained filters, but where the effluent is well supplied with dissolved oxygen there are grave doubts in the mind of the writer as to whether it is economically practicable to design and operate a sprinkling filter so as to promote relatively high nitrification.

Undoubtedly we are in need of more reliable means for measuring the practical results accomplished in removing the objectionable putrefying constituents of sewage. The "Salt-peter Method for Determining the Strength of Sewages," as presented in Dr. A. Lederer's recent notes on this subject, may put a different aspect on these comparative studies.

QUALITY OF SEWAGE.

Undoubtedly the age, strength and character of the applied sewage are factors to be considered in dealing with the work accomplished by sprinkling filters. It is quite significant to the writer's thought that the sewage applied to the test filters at Baltimore was very fresh sewage from a small suburban area immediately adjoining the station. The sewage at Reading and Plainfield is also relatively fresh. At Lawrence the sewage is stale and more or less advanced along the lines of anaërobic decomposition. This was true as described by the writer in the 1894 Report of the Massachusetts State Board of Health, page 459. This "staleness" of the Lawrence sewage has quite likely increased rather than decreased in recent years. The sewages at Worcester and Gloversville are characterized by their mixture with trade wastes, and these may have been factors of substantial significance.

The English data, quoted by Mr. Eddy to the effect that the work accomplished by sprinkling filters is substantially the same per volume of material, were presumably obtained with

stale rather than fresh sewage. Perhaps the long period of travel of the Lawrence sewage through the 4 000-ft. length of galvanized-iron pipe may be a factor explaining the data pointing to a result different from the English conclusion and diametrically opposed to the data from Baltimore, Reading, etc. Lack of aëration of the influent, such as furnished by sprinkler nozzles elsewhere, may be of significance.

RELATIVE PURIFICATION BY ROYAL COMMISSION STANDARDS.

In the absence of any definitely accepted method of comparing purification effected by filters, the writer has had his staff study the use of the proposed Royal Commission method for this purpose. This method is not presented by its author, Dr. McGowan, as being at all conclusive, and it is based, of course, on a limited number of experimental data; nevertheless, it has the merit of being suitable for quantitative comparison. This Royal Commission method is an attempt to put in numerical form the various elements entering into the strength of a sewage applied to a filter and the effluent coming from a filter and, combining these figures for strength or oxidizability with the rate of dosing of the sewage, there is obtained a definite numerical purification figure which is said to be suited for comparative work.

This method, originated by Dr. George McGowan, may be found in the Fifth Report of the Royal Commission on Sewage Disposal, on pages 16 and 107. Detailed information with the bases on which the formulæ used are derived may be found in the Fourth Appendix to the Fifth Report of the Royal Commission on Sewage Disposal, particularly pages 1 to 50.

The oxidizability, which is called the strength of the sewage applied, is to be measured by the following formula:

$$S = (\text{Ammon. N} + \text{Organic N}) \times 4.5 \\ + (\text{Oxygen absorbed in 4 hours}) \times 6.5.$$

Nitrogen and oxygen are to be expressed in parts per 100 000.

The strength of a filtered effluent is measured by Dr. McGowan as follows:

$$\begin{aligned} \text{Strength} &= (\text{Ammon. N} + \text{Organic N}) \times 4.5 \\ &+ (\text{Vol. matter of suspended solids}) \times 2 \\ &- \text{nitric nitrogen} \times 3. \end{aligned}$$

The amount of purification effected, or, as expressed by Dr. McGowan, the unit of purification per cubic yard of material, is equal to the difference in strength between the influent and effluent, multiplied by the gallons of sewage per cubic yard of material treated per day.

The theory on which these formulæ is based is that the so-called strength of either influent or effluent, as expressed by the formula, is equal to the amount of oxygen in parts per 100 000 required completely to oxidize the sewage. In the formula for the effluent a deduction is made for the oxygen present in the form of nitrates by deducting three times the nitric nitrogen from the strength as shown by the other part of the formula. The difference between the strength of the influent and the effluent represents the loss of oxidizability in parts of oxygen per 100 000 effected by the purification treatment.

The writer uses the above-stated formula in analyzing the various observations which have been made in this country. In this connection he wishes to call attention to the fact that in the formula for the strength of sewage effluents from filters a subtraction is made corresponding to the amounts of nitrates present, and as it is well known that a deep filter effects a relatively higher degree of nitrification than shallow filters, this deduction for nitrates favors relatively the deep filter. A later suggestion of Dr. McGowan is to be found on page 50 of the Fourth Appendix to the Fifth Report, as follows:

"With regard to the calculation of the unit of purification per cubic yard of filter, we think — on further consideration — that it would be more correct not to give credit for the nitrate remaining in the effluent. The strength of a sewage liquor is based upon the amount of oxygen required for the complete oxidation of the liquor by atmospheric or dissolved oxygen, the nitrogen (at all events, much the greater part of it) remaining in the diluted liquid in the form of nitrate."

If this modified form of strength formula were to be used,

not making deduction from the strength of the effluent because of the nitrates present, the resultant figures would be more favorable to the form of filter effecting the smaller amount of nitrification. The writer does not, however, use this modified formula, but uses the original form and wishes only to call attention to the fact that the error in using the original form, if any, as between the original formula and the one later suggested by Dr. McGowan, favors the deep filter as compared with the shallow one.

Examining first the data presented in Table 1 of Mr. Eddy's paper, we find records given for the Gloversville experimental plant for a period of three months for each of the three filters. The writer does not wish to question the correctness of these records as reported by Mr. Eddy, for the particular time which these records cover, and no doubt from Mr. Eddy's familiarity with this experimental plant he has given correct figures, but the writer has been unable to find these figures in the original 1909 printed Gloversville report and has been compelled to take from this original printed report figures as reported in order to use Gloversville tests for comparative purposes. Taking practically the whole run of these filters Nos. 1, 2 and 3 for a period of ten months beginning at the beginning of September, 1908, and ending at the end of June, 1909, and taking the rate of filtration as given in Appendices I, J and K, pages 211 to 250 inclusive, of the report, we get the following Table 1.

The quality of the influent to the filters and the effluent from the filters is to be found in this 1909 report as follows. For filter No. 1, on page 100; filter No. 2, on page 103; filter No. 3, on page 104. The tables on these three pages give what is called the averages of all analyses of influent and effluent. These averages may not be absolutely identical for the same period as those of the average rate shown here in Table 1, and it may extend for a somewhat longer period than that of Table 1. There is no reason, however, to expect that there will be any substantial difference, and we can practically take the analyses of these pages quoted as corresponding to the rate of Table 1.

Using the analyzed results, Table 2 following shows the purification effected by each of the three filters in question:

TABLE 1.

AVERAGE RATE OF FILTRATION, IN MILLION GALLONS PER ACRE DAILY, GLOVERSVILLE EXPERIMENTAL FILTERS.

Month.	FILTER NO.		
	1.	2.	3.
September, 1908.....	0.60	0.69	0.60
October.....	0.78	0.78	0.70
November.....	1.00	1.00	1.00
December.....	1.18	1.06	1.00
January, 1909.....	1.18	1.06	1.00
February.....	1.18	1.06	1.00
March.....	1.18	1.06	1.00
April.....	1.18	1.06	1.00
May.....	1.18	1.06	1.00
June.....	1.18	1.06	1.00
Average.....	1.06	0.99	0.93

TABLE 2.

GLOVERSVILLE EXPERIMENTAL FILTERS. RECEIVING SEPTIC TANK SEWAGE.

	FILTER NO.		
	1.	2.	3.
Depth of stone, feet.....	10	7	5
Size of stone, inches.....	1½-2	1½-2	1½-2
Rate of dosing, m.g.d. acre.....	1.06	.99	.93
Rate of dosing, gallons per cu. yd. per day,	66	88	115
Influent: Free ammonia, ppm.....	14	15.2	14
Organic nitrogen, ppm.....	14	15.3	14
Oxygen consumed (5 min. boiling), ppm.....	61	68	62
Strength, $\frac{4\frac{1}{2}(N+O)}{10}$, pp 100 000	38.8	40.2	39.4
Effluent: Free ammonia, ppm.....	8.0	8.6	11.5
Organic nitrogen, ppm.....	3.5	5.0	5.8
Nitrates, ppm.....	4.8	3.6	1.6
Volatile suspended solids, ppm.....	22	32	29
Strength, $\frac{4\frac{1}{2}N+2V-3n}{10}$, pp 100 000.....	7.6	10.7	12.2
Reduction of strength.....	31.2	29.5	27.2
Purification units per cubic yard daily.....	2 060	2 600	3 130

In considering the data of these experiments, it is to be noted that the oxygen-consumed test is given on the basis of the oxygen taken from permanganate on five minutes' boiling. This oxygen figure will be materially greater than will be obtained by the four-hour test used as the basis in the English formula, and to make allowance for the different figures the writer has used a multiplier of 4.5 instead of 6.5 for the oxygen consumed. This may not be at all exact, but the error introduced is not substantial, and should not materially affect the result.

On the basis of all the Gloversville tests recorded, it seems that stone in the 10-ft. filter effects the purification of 2 060 units per cubic yard per day; in a 7-ft. filter, 2 600 units; and in the 5-ft. filter, 3 130 units.

Passing now to the next series of data reported by Mr. Eddy, the test of the Worcester, Mass., filters, here again the writer is unable to identify the particular period covered by these tests reported by Mr. Eddy and is unable to test the accuracy of the figures shown or to judge them by his own methods of computation. The results reported for the deep filters seem to be substantially better than those of the shallow filters. There are some variable factors, however, in these tests which make the comparison as reported unsatisfactory. The biggest item of difference appears in the Table 1 of Mr. Eddy's paper, where it is stated that the sewage applied to Filters D, F and E is settled sewage and the sewage applied to Filters G and H, the deeper filters, is the effluent from Imhoff tanks. The fact that the tests are not made at the same time makes comparison a very difficult matter. Another factor is stated in Mr. Fales's report appended to the annual report of the superintendent of sewers of Worcester for the year ending November 30, 1912, on pages 57 and 58, where he states:

"In considering the relative efficiency of the 10-ft. filter, conditions of operation must again be taken into account. During the operation of the 10-ft. filter, Worcester nozzles have been in use, and the distribution has been much better than we have ever attained before. It is probable that the increased efficiency of the filter is due largely, if not solely, to the improvement in the distribution."

Still another difficulty in the proper comparison of these tests is the fact that the effluent analysis reported is the analysis with the suspended matters in the effluent removed by sedimentation. This will effect an apparent increase in the purification units to be obtained from each filter, but it is not known whether this increase will be the same for all filters and for the whole period covered by the tests.

The writer feels that the tests as reported are not in such shape that a comparison will lead to any final conclusion; he gives the figures of these tests below and the calculations obtained from them for the sake of completeness in the following table.

The shallow filters, Filters D, E and F, have results reported in the annual report of the superintendent of sewers for the year ending November 30, 1910, page 748. Table 3 gives the data and calculations obtained from this series of tests.

TABLE 3.

WORCESTER EXPERIMENTAL FILTERS RECEIVING SETTLED SEWAGE.
SEPTEMBER, 1909, TO SEPTEMBER, 1910.

(All data in parts per 100 000.)

	FILTER No.		
	D.	E.	F.
Depth of stone, feet	5.0	7.5	7.5
Size of stone, inches	$\frac{3}{4}$ -2 $\frac{1}{2}$	$\frac{1}{2}$ -1 $\frac{1}{2}$	$\frac{3}{4}$ -2 $\frac{1}{2}$
Rate of dosing, m.g.d. acre	.70	1.00	1.00
Rate of dosing, gallons per cu. yd. per day,	93	83	83
Influent: Free ammonia	2.70	2.70	2.70
Albuminoid ammonia	.52	.52	.52
Residual organic nitrogen	.66	.66	.66
Oxygen consumed (2 min. boiling)	8.05	8.05	8.05
Strength, 4 $\frac{1}{2}$ N+6 $\frac{1}{2}$ O	67.1	67.1	67.1
Effluent: Free ammonia	2.13	1.85	1.83
Albuminoid ammonia	.17	.13	.13
Residual organic nitrogen	.16	.13	.16
Nitrates	.23	.47	.34
Strength, 4 $\frac{1}{2}$ N-3n	8.6	6.4	7.4
Reduction of strength	58.5	60.7	59.7
Purification units per cu. yd. per day	5 400	5 000	4 950

In these Worcester tests the oxygen consumed is reported by the two minutes' boiling method. It is assumed for the purpose of comparison that the oxygen consumed as given by this test will be practically the same as that obtained by the four-hour English tests on which the formulæ are based.

The results obtained in the Worcester experiments on the 10-ft. filter dosed with Imhoff tank effluent as obtained from the 1912 annual report, pages 54 and 55, are shown in detail in Table 4 accompanying.

TABLE 4.
WORCESTER EXPERIMENTAL FILTERS. 1912 REPORT. RECEIVING
IMHOFF TANK EFFLUENT. FILTER EFFLUENT TESTED AFTER 2.3
HOURS' SETTLEMENT.

(All data in parts per 100 000)

	FILTER NO.	
	G.	H.
Depth of stone, feet.....	10	10
Size of stone, inches.....	$\frac{1}{2}$ -1 $\frac{1}{2}$	$\frac{3}{4}$ -2 $\frac{1}{2}$
Rate of dosing, m.g.d. acre.....	1.553	1.563
Rate of dosing, gals. per cu. yd. per day.....	96	97
Influent: Free ammonia.....	2.43	2.43
Albuminoid ammonia.....	.67	.67
Residual organic nitrogen.....	1.067	1.067
Oxygen consumed.....	11.90	11.90
Strength.....	93.7	93.7
Effluent: Free ammonia.....	1.78	1.85
Albuminoid ammonia.....	.23	.25
Residual organic nitrogen.....	.28	.30
Nitrates.....	.60	.51
Strength.....	7.9	7.6
Reduction of strength.....	85.8	86.1
Purification units, per cu. yd. per day.....	8 200	8 350

Turning now to the Lawrence tests, here again the writer refers to the original data in the absence of being able to identify Mr. Eddy's records. In the year 1908 Annual Report of the Massachusetts State Board of Health, page 370 and following, is given a summary of the previous ten years' tests of various

filters, and of these, Nos. 135, 136, 247, 248 and 222 are reported in some detail. Table No. 5, following, gives the tabulation of the data reported in this 1908 report and tabulations of the purification unit.

TABLE 5.

LAWRENCE EXPERIMENTAL FILTERS. 1908 REPORT, PP. 370 ET SEQ.
(All data in parts per 100 000.)

Filter No.....	135	136	247	248	222
Period of trials.....	9 yrs. 1 mo.	9 yrs. 1 mo.	4 yrs. 3 mos.	4 yrs. 4 mos.	5 yrs. 5 mos.
Depth, feet.....	10.0	10.0	5.0	8.0	8.0
Size of stone, inches.....	$\frac{1}{4}$ -1	$\frac{1}{4}$ -1	$\frac{1}{4}$ -1	$\frac{1}{4}$ -1	
Rate of dosing, m.g.d. acre.....	1.512	1.797	1.465	1.490	1.394
Rate of dosing, gals. per cu. yd. per day...	94	112	182	116	108
Influent: Free ammonia.....	4.70	4.59	4.33	4.41	3.52
Kjedahl nitrogen.....	1.04	.98	1.14	1.20	1.19
Oxygen consumed (2 minutes).....	3.64	3.56	4.17	4.29	3.43
Strength.....	45.7	44.5	48.3	49.7	40.7
Effluent: Free ammonia.....	1.63	1.99	2.86	2.34	2.72
Kjedahl nitrogen.....	.40	.48	.97	1.03	.57
Nitrates.....	2.55	2.21	.612	1.77	.45
Strength.....	.25	2.9	13.14	8.0	11.35
Reduction of strength.....	45.5	41.6	35.2	41.7	29.3
Purification units per cu. yd. per day....	4 280	4 660	6 400	4 830	3 160

It is to be noted that here, too, there is given no record of the volatile matter in the suspended solids, and the strength of the filter effluent is, therefore, calculated while ignoring this question of the volatile suspended solids.

Coming now to the experimental filters at Baltimore, as reported by the Baltimore Sewerage Commission in the 1911 annual report, which tests formed the basis of the writer's original paper, we get Tables 6 and 7, taken from pages 55 and 57 of this 1911 report. The rates of filtration are not given in the original report beyond the intimation that they were uniform for the various depths of filters, and the statement that the average rate was approximately 3.3 million gallons per acre of filter surface per day. For the purpose of making these Tables 6 and 7 and to simplify comparison, the writer has assumed a

uniform rate of one million gallons per acre per day, and the resulting figures for purification are no doubt somewhat less than that actually obtained.

Examined in the way outlined above, some of the tests made, such as the Gloversville test and the Baltimore test, seem to indicate very definitely a greater purification effected per cubic yard of stone by the shallow filters. The Worcester tests do not lead to any conclusion, because of the varying conditions under which the various tests were made. The Lawrence earlier tests seem to show that there is no notable difference in the output of the filters of various depths. In comparing these tests, however, it should be noted that the Gloversville and Baltimore tests do report the amount of volatile suspended solids in the filter effluent, and that these are properly accounted for in the formula and in the purification thus obtained. Neither the Worcester nor the Lawrence test report these volatile suspended solids, and therefore no allowance is made in figuring purification units.

It is well known that some part of the settling solids in the effluent of coarse grain sprinkling filters is putrescible.

TABLE 6.

BALTIMORE EXPERIMENTAL FILTERS. 1911 REPORT OF BALTIMORE SEWERAGE COMMISSION, TABLE B, PAGE 55.

	6	9	12
Depth of filter, feet.....	1-2	1-2	1-2
Size of stone, inches.....	1.0	1.0	1.0
Rate of dosing, m.g.d. acre, <i>assume</i>	104	69	51
Rate of dosing, gals. per cu. yd. per day.....	19	19	19
Influent: Free ammonia, ppm.....	16	16	16
Organic nitrogen, ppm.....	50	50	50
Oxygen consumed, ppm.....	47.3	47.3	47.3
Strength, pp. 100 000.....	15	11	9
Effluent: Free ammonia, ppm.....	12	10	10
Organic nitrogen, ppm.....	8	15	18
Nitrates, ppm.....	50	33	27
Volatile suspended solids, ppm..	18.4	10.7	7.6
Strength, pp. 100 000.....	28.9	36.6	39.7
Reduction of strength.....	3 000	2 500	2 030
Purification units per cu. yd. per day....			

TABLE 7.

BALTIMORE EXPERIMENTAL FILTERS. 1911 ANNUAL REPORT,
TABLE D, PAGE 57.

Depth of filter, feet.....	4.5	7.5	10.5
Size of stone, inches.....	1-2	1-2	1-2
Rate of dosing, assumed, gals. cu. yd. per day.....	138	83	59
Influent: Free ammonia, ppm.....	18	18	18
Organic nitrogen, ppm.....	10	10	10
Oxygen consumed, ppm.....	42	42	42
Strength, pp. 100 000.....	38.5	38.5	38.5
Effluent: Free ammonia, ppm.....	16	11	7
Organic nitrogen, ppm.....	8	8	7
Nitrates, ppm.....	3	11	17
Volatile suspended solids, ppm..	36	27	24
Strength, pp. 100 000.....	15.8	9.7	5.6
Reduction of strength.....	22.7	28.8	32.9
Purification units per cu. yd. per day.....	3 130	2 400	1 940

CONSTRUCTION FACTORS.

If it is true that in the treatment of a given sewage its stability or non-putrescible condition is brought about in sprinkling filters of varying depths to the same extent per cubic yard of material in the bed, there is no doubt about deeper beds being cheaper than shallower ones; this is stated by the writer in his book on "Sewage Disposal," page 703. On that assumption, the deeper beds would undoubtedly be cheaper if we were sure that surface clogging, as experienced at Reading, would not increase the operating costs and if we were also certain that high nitrification, comparatively speaking, is worth securing in addition to reducing the organic matter to a point where the effluent will not putrefy.

Mr. Eddy's point that the distributing system is more likely to vary in proportion to the area of the filter than with the quantity delivered has an element of truth, in that the cost of the distribution system will depend on both of these factors, although we have made no detailed comparisons for the approximate studies hitherto undertaken. There are rather striking differences in the unit costs of floors, false bottoms, walls, galleries and distributors, between Mr. Eddy's figures based on

his Fitchburg prices and those used by the writer in his original paper. Local factors of design and market prices are no doubt abundantly capable of explaining these differences. The higher these unit costs are for the filter floor, the greater will be the benefit of deeper filters, comparatively speaking.

As to the writer's unit prices for the structures above mentioned, there is nothing that can be added except that they are in accordance with his repeated experiences. Eliminating the item of filtering material (broken stone), his unit prices are in accordance with the results of the recent letting at Plainfield, N. J., and substantially conform to the prices obtained in 1913 at Baltimore, Md.; at Reading, Pa.; and Columbus, Ohio; and Atlanta, Ga.

As to broken stone, the Fitchburg price of \$1.95 per cubic yard is no doubt more representative of New England conditions than the \$1.50 price used by the writer. The low price was used by the writer with the intent of making the comparison fair to the deep filters, as the lower the price of broken stone, the less is the possible advantage which might accrue to the shallower filters.

It is perhaps worth while to point out that excavation, embankments and some minor appurtenances are not included in the figures for the writer's sprinkling filter costs. The total cost of an installation, including all factors not varying with the depth, will be markedly higher than the base prices given.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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TOILET REGULATIONS FOR INDUSTRIAL ESTABLISHMENTS. REPORT OF COMMITTEE.

BOSTON, November 3, 1914.

Mr. BERTRAM BREWER, CHAIRMAN SANITARY SECTION,
BOSTON SOCIETY OF CIVIL ENGINEERS:

Sir, — Pursuant to instructions, the committee appointed by you to consider the regulations for toilet facilities in industrial establishments, a subject now under consideration by the State Board of Labor and Industries, has completed its study and submits the following

REPORT.

The committee visited the Bureau of Labor and Industries and received from its sanitary engineer copies of a draft of proposed regulations and other contributory data.

In order to prepare itself to criticise the proposed regulations intelligently, your committee visited several industrial establishments employing workers of various nationalities with widely differing personal habits. It has also held several meetings to discuss the questions involved; it has investigated the laws and regulations of other states and the practice of certain large corporations; and it has consulted the available literature bearing upon the problem and several engineers who have special knowledge in the premises.

Your committee finds that the regulations proposed by the State Board of Labor and Industries are generally fitting and proper and not burdensome to the employer of labor. Furthermore, they should afford sufficient protection to the employee. On the other hand, your committee has suggested certain changes in the text of the regulations in the interest of clearness and consistency.

Because the condition in which toilet rooms are maintained may depend in large measure upon the ideals of certain employees, and as ideals of proper cleanliness and care differ widely among different classes of employees, there appears to be no way of obtaining proper conditions except through a system of state inspection and supervision, supported by adequate police power.

At the present time the manufacturers of the state are complaining of too many inspections and that the very frequent admission of inspectors, both those authorized by the state and those representing private associations, interferes in no small degree with the work of the various establishments. This annoyance should be reduced to the minimum consistent with the health and welfare of the employees; and if the state factory inspection could be made by one board, even though it requires more than one kind of inspection, conflict of authority might be avoided and the manufacturers relieved of some of the annoyance of which they complain.

The proposed regulations, with the changes suggested by the committee, are transmitted with this report.

Respectfully submitted,

ROBERT SPURR WESTON,
GEORGE A. CARPENTER,
RICHARD A. HALE,

Committee.

**Toilet Regulations for Industrial Establishments
Recommended by the Sanitary Section of the
Boston Society of Civil Engineers.**

(Adopted December 9, 1914.)

TOILET FACILITIES.

I.

WHERE REQUIRED AND SEX DESIGNATION.

In every establishment where persons are employed, there shall be provided within reasonable access a sufficient number of proper water-closets, earth closets or privies, and wherever ten or more persons of both sexes are employed together, separate water-closet compartments or toilet rooms shall be provided for each sex, and shall be plainly so designated.

No person shall be allowed to use a closet or privy which is designated for the use of persons of the opposite sex.

II.

NUMBER REQUIRED.

The number of seats shall not be less than one to every twenty-five (25) males and one to every twenty-five (25) females, based upon the maximum number of persons, of either sex, employed at any one time, except that where urinals are provided, the number of seats required may be decreased by one for each urinal installed; but the total number of seats, however, shall not be less than two thirds the number required above.

III.

LOCATION.

Water-closets and urinals must be readily accessible to the persons using them. In no case may a closet be located more than one floor above or below or more than 300 ft. distant from the regular place of work of the person using the same.

In tenant factories, mercantile or office buildings, the owner shall provide separate toilets within reasonable access, as above defined, for the common use of the tenants.

IV.

PRIVACY.

(a) Existing Installations.

The entrance to every water-closet compartment, which opens directly into a room, hall or passageway in a building where both sexes are employed, or room, hall or passageway frequented by both sexes, shall be screened by a screen or vestibule at least six (6) feet in height.

(b) Future Installations.

Every water-closet compartment hereafter installed shall be located in a toilet room, or shall be built with a vestibule to screen the interior from view.

(c) All Installations.

Where separate toilets for each sex adjoin, they shall be separated by solid partitions, and the entrances shall be as remote as possible. They shall not open into a common ante-room.

V.

VENTILATION.

(a) Existing Installations.

Every water-closet compartment, excepting as hereinafter provided, shall be ventilated directly to the outside air by a window, skylight or other suitable opening.

All water-closets which are not ventilated directly to the outside air by a window, skylight or other opening shall be entirely enclosed in a compartment or toilet room, by either extending the side walls to the ceiling or by independently ceiling them over at a minimum height of eight (8) feet. This compartment or toilet room shall then be ventilated by either:

1. An exhaust system; or

2. A stack to the roof at least 6 in. in diameter.

Wherever practicable, these toilets shall be relocated so that they will be exposed directly to the outside light and air, in accordance with the requirements for new installations.

(b) Future Installations.

Every water-closet compartment hereafter constructed shall be ventilated directly to the outside air by a window, skylight or other suitable opening. Where the water-closet compartments ventilate into an air shaft, the area of such shaft in square feet must not be less than 20 per cent. of the height of the shaft in feet. If this air shaft is covered with a skylight, the net area of the openings at the top must be at least one and one-half times the area required for the shaft.

VI.

LIGHTING.

(b) Future Installations.

The minimum amount of window space for every toilet room in which one urinal or seat is hereafter installed shall be four (4) square feet, and for each additional urinal or seat one (1) square foot additional window space shall be provided.

(c) All Installations.

All windows must be so constructed that they can be readily opened to at least one half their total area.

Every toilet room or water-closet compartment shall be so lighted that all parts of the room or compartment are easily visible at all times during working hours. If daylight is not sufficient for this purpose, artificial illumination shall be maintained.

VII.

SIZE OF TOILET ROOM.

In all water-closet compartments hereafter constructed, there shall be at least ten (10) square feet of floor space and 80 cubic feet of air space per urinal or seat installed.

VIII.

TYPE OF WATER-CLOSET.

All water-closets shall be provided with ample water for flushing.

All water-closets hereafter installed shall have individual bowls made of porcelain or vitreous earthenware; they shall be provided with seats made of wood or other non-heat-absorbing material, which shall be coated with varnish or some other waterproof substance.

All future installations of water-closets in inside rooms shall be provided with local seat vents connected with a stack or chimney having an area of cross section of not less than three (3) square inches per closet.

IX.

ENCLOSING WOODWORK.

(a) Existing Installations.

All woodwork enclosing the bowl of the closet shall be removed and the space within the compartments shall be painted with some light-colored non-absorbent paint.

(b) Future Installations.

The bowl of the closet shall be free and clear so that the space behind and below may be readily cleaned.

X.

PARTITIONS AND WALLS.

(b) Future Installations.

Hereafter, when more than one water-closet is installed in a toilet room, partitions shall be provided between the seats. These may be of wood if covered with paint or some other non-absorbent material. They shall be not less than six (6) feet high, and, where practicable, shall not extend nearer the ceiling or floor than one foot. They shall be at least twenty-eight inches (28 in.) apart.

(c) All Installations.

The enclosing walls shall be substantially constructed and

designed to secure privacy. All outside walls, unless constructed of glazed tile, brick, etc., shall be kept well painted with a light-colored non-absorbent paint, varnish or other impervious compound.

XI.

FLOORS.

(b) *Future Installations.*

The floor of every water-closet compartment or toilet room hereafter installed, and the side walls, to a height of nine (9) inches, shall be constructed of material impervious to moisture, and which has a smooth surface.

(c) *All Installations.*

The floors of all water-closet compartments and toilet rooms shall be kept in good repair, and free from large cracks or holes.

XII.

DOORS.

(b) *Future Installations.*

All water-closet compartments hereafter installed in men's toilet rooms shall be provided with doors at least three (3) feet in height and they shall be set twenty-four (24) inches above the floor.

(c) *All Installations.*

All water-closet compartments inside a toilet room used by females shall be provided with a door at least forty-two (42) inches high and furnished with a suitable fastener.

XIII.

URINALS.

(b) *Future Installations.*

Hereafter wherever urinals are installed, the floors in front for a distance of at least twenty-four (24) inches shall slope to the drain.

The use of the iron trough type is prohibited, and all urinals

shall be made of impervious non-corrosive materials, shall be individual, and preferably of the wall or vertical slab type.

(c) All Installations.

Where more than ten (10) males are employed a urinal shall be provided; urinals shall be provided in the ratio of one urinal to every forty (40) males, based upon the maximum number of persons employed at any one time. Two (2) feet of wall urinal shall be considered as an equivalent of one urinal.

The floors shall be constructed of impervious material to at least twenty-four (24) inches distant.

XIV.

HEATING.

(b) Future Installations.

In all water-closets hereafter installed, the heating facilities shall be so arranged as to permit a thorough cleaning of the floors and walls.

(c) All Installations.

It is recommended that all water-closet compartments and toilet rooms shall be kept heated during the working hours to at least fifty (50) degrees Fahrenheit.

XV.

MISCELLANEOUS.

Where practicable, an adequate supply of toilet paper shall be provided in every water-closet compartment.

Any indecent pictures or words shall be removed from the walls or partitions of the toilet rooms.

XVI.

MAINTENANCE.

All toilets and urinals shall be kept clean. Regular and thorough cleansing shall be practiced. Disinfection alone is not to be relied upon. In every establishment there shall be one person who shall have direct charge of and be held responsible for the cleanliness of all sanitary appliances installed.

WASHING FACILITIES.

I.

WHERE REQUIRED AND SEX DESIGNATION.

In every establishment where persons are employed there shall be provided, within reasonable access, a sufficient number of proper washing facilities, and where ten or more males and ten or more females are employed together, separate washing facilities shall be provided for each sex, and shall be plainly so designated.

II.

NUMBER REQUIRED.

The number of wash bowls, sinks or other appliances shall not be less than one to every thirty (30) persons, based upon the maximum number of persons using the same at any one time. Twenty (20) inches of sink will be considered as an equivalent of one wash bowl.

In special industries or departments where there is undue exposure to poisonous substances or liquids, or where the work is especially dirty, one may be required for every five (5) persons, and in these cases they shall be provided with clean, running hot and cold water.

III.

LOCATION.

The washing facilities provided must be within reasonable access as above defined for toilets, and at least one wash bowl, sink or other suitable appliance shall be provided in or adjacent to every toilet room.

IV.

LIGHTING.

All washing facilities shall be clearly lighted at all times during working hours.

V.

CLEANLINESS.

All washing facilities or appliances and the floors in and around the same shall be kept clean, and regular and thorough cleansing shall be practiced.

VI.

MISCELLANEOUS.

Where common sinks are provided, these shall be furnished with individual wash basins. One tap for each 20 in. of wall sink, or one pair of taps for each 20 in. of double sink, each supplied with clean running water, shall be provided with the sinks.

In the above regulations, no specific rules are given for privies. There are few industrial establishments in Massachusetts which are not provided with running water, and most of the establishments where connection with sewers is not possible could arrange to drain sanitary fixtures into cesspools or suitable independent sewage disposal plants. Where privies are unavoidable, they should under no circumstances communicate directly with any work-room, but should be separated by a vestibule open to light and air. Such other regulations for closets as are pertinent should be applied to privies.

It is recommended that all privies be screened to prevent the access of flies and other insects to the dejecta, which latter should be received in a water-tight receptacle and removed at frequent intervals; in other words, the so-called "bucket system" should be used. The so-called water-tight privy vaults, if used alone, are not considered satisfactory.

Where the bucket system is used, it is recommended that dry earth or sand be supplied in each privy, and that if possible the dejecta be disinfected to prevent the spread of infection.

While the fixtures and plumbing are important from a public health standpoint, the paramount requirements are an abundance of air and light, with privacy and cleanliness.

Cleanliness is the most important factor. As a general rule,

it is true that the most modern toilet facilities, when neglected, are far less satisfactory than older and cruder fixtures, well cared for.

A dark toilet compartment is usually a dirty one; therefore, toilet rooms and compartments should be well lighted.

Closets without local vents generally produce disagreeable odors, and therefore seat ventilation is recommended, especially where closets are not directly exposed to outside light and air. If the seats be ventilated and the requirements for cleanliness, light and privacy be met, there appears to be no reason why closets in existing inside rooms should not be permitted.

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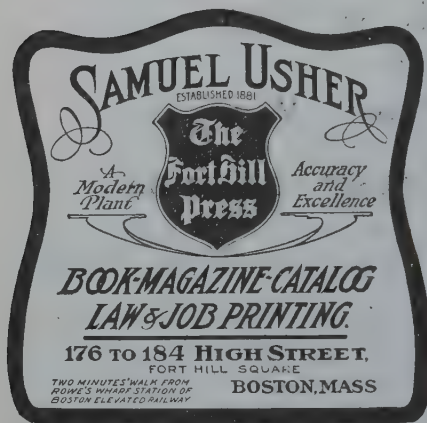
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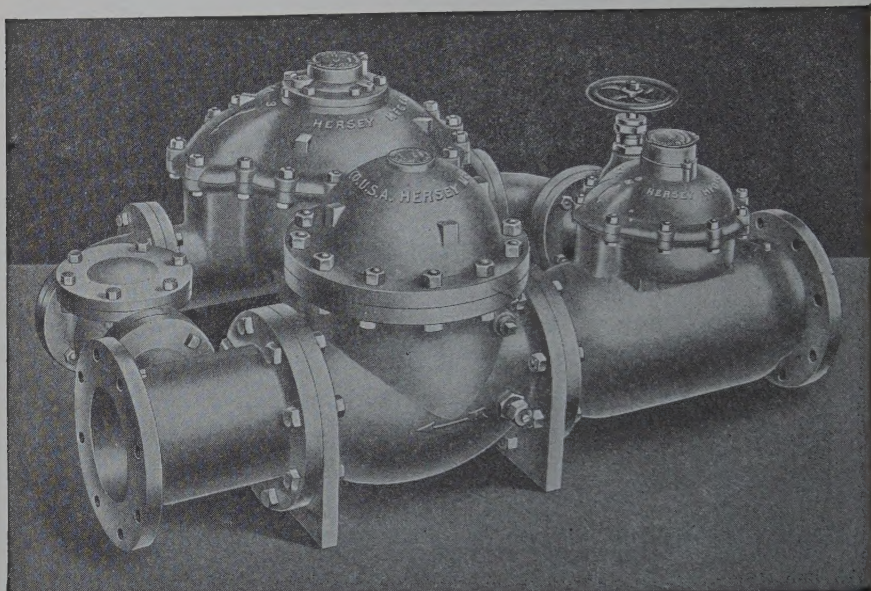


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